FARM BULLETIN NO. 9

Cultivation of Eucalyptus citriodora Hook. For Its Essential Oil

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Introduction

The eucalypts are highly ornamental trees with their characteristic bark, cylindrical shining stem, majestic crown of branches and leaves. The discovery of the eucalypts dates back to the year 1770 when Joseph Banks collected a sample from East Coast of Australia during Captain James Cook's first voyage to the Pacific Ocean and naming of this sample as Eucalyptus by a French Botanist in 1778. This name is derived from two Greek words, "eu", meaning "Well" and "Kalypts", meaning "I cover" based on the nature of the lid covering the flowers before blooming. The genus has ever since been a topic of intensive scientific investigation.

Although the genus is a native of Australia, several of its important species have naturalised in various tropical and subtropical countries. Some of the species produce quality timber, some possess paper-pulping quality while certain others are reputed for their industrial, medicinal and perfumery grade oils. The perfumery industry has evinced great interest in *E. citriodora* Hook. after the discovery of its essential oil in 1882. Its leaves normally contain 0.5-4% essential oil, although physiological races with up to 7.0% oil are also reported. India's demand for this oil is mainly met with by imports since a very small quantity is produced indigenously. Over Rs 2 million worth oil and its chief constituents are annually imported into India. Because of the extensive demand for citronellol, the main constituent of *E. citriodora* oil, there is considerable scope for cultivation of this tree. In addition, the wood obtained can be used for paper pulp.

Botanical Description

The genus *Eucalyptus* contains more than 700 species and belongs to the family Myrtaceae, sub-family Leptospermoideae, tribe Leptospermeae and sub-tribe Eucalyptineae. Based on their habit and size, the eucalypts have as well been classed as tall or mallees. Amongst the tall species, *E. ragans*, the tallest hard-wood plant of the world, occurring in the State of Victoria

attains a height up to 114 m. and girth up to 24 m. at 2 m. above ground level. The mallees are small, shrubby, multi-stemmed plants. On the basis of shape, size and mode of dehiscence of anthers, the genus is broadly sub-divided into six sub-sections. These are : (1) Renantherae, (2) Renantheroideae, (3) Porantheroideae, (4) Terminales, (5) Platyantherae, and (6) Macrantherae. Yet another classification based on the characters of bark, timber, pairs of opposite juvenile leaves, inflorescence and fruits etc. has been proposed. However, a satisfactory classification of the genus is still wanting.

E. citriodora Hook. is a tall tree growing up to 20 m. with a crown of branches and leaves at the top. It has 22 chromosomes and shows a distinct apical dominance. If the apical region is damaged, side shoots emerge and grow vertically. Lateral spread of branches at lower levels is extremely rare. It exhibits a marked heterophylly. Five distinct types of leaves, (1) cotyledonary, (2) seedling, (3) juvenile (Fig. 1-a), (4) intermediate (Fig. 1-b) and (5) adult leaves (Fig. 1-c), are observed at various stages of the life-cycle of the plant. The young seedlings, after cotyledonary stage, develop 5-10 pairs of seedling leaves of varying shapes and sizes. This is followed by formation of juvenile leaves which are opposite in disposition up to certain stage but later become alternate and are quite distinct from mature leaves. The intermediate leaves represent a gradual transition from juvenile to adult leaves. In certain cases the intermediate leaves are very difficult to distinguish. They are larger and coarser than both the juvenile and adult leaves. The juvenile leaves often differ from the adult leaves in their texture, pubescence, glaucousness, etc. The former are usually dorsi-ventral and hence structurally different on both the surfaces while the latter are almost isobilateral, thus identical on both surfaces. The juvenile leaves are covered with trichomes and adult ones are almost naked.

The adult leaves are lanceolate, up to 15 cm. long and 3 cm. broad, acuminate, with venation finely marked, lateral veins numerous, oblique, parallel and midly spreading, intramarginal veins do not reach the margin. Flowers are numerous in axillary panicles: calyx-tube hemispherical to cylindrical; anthers are adnate (Fig. 1-d). Fruits are ovoid, truncate, contracted at the edge, rim thin and valves opening downwards (Fig. 1-e, f).

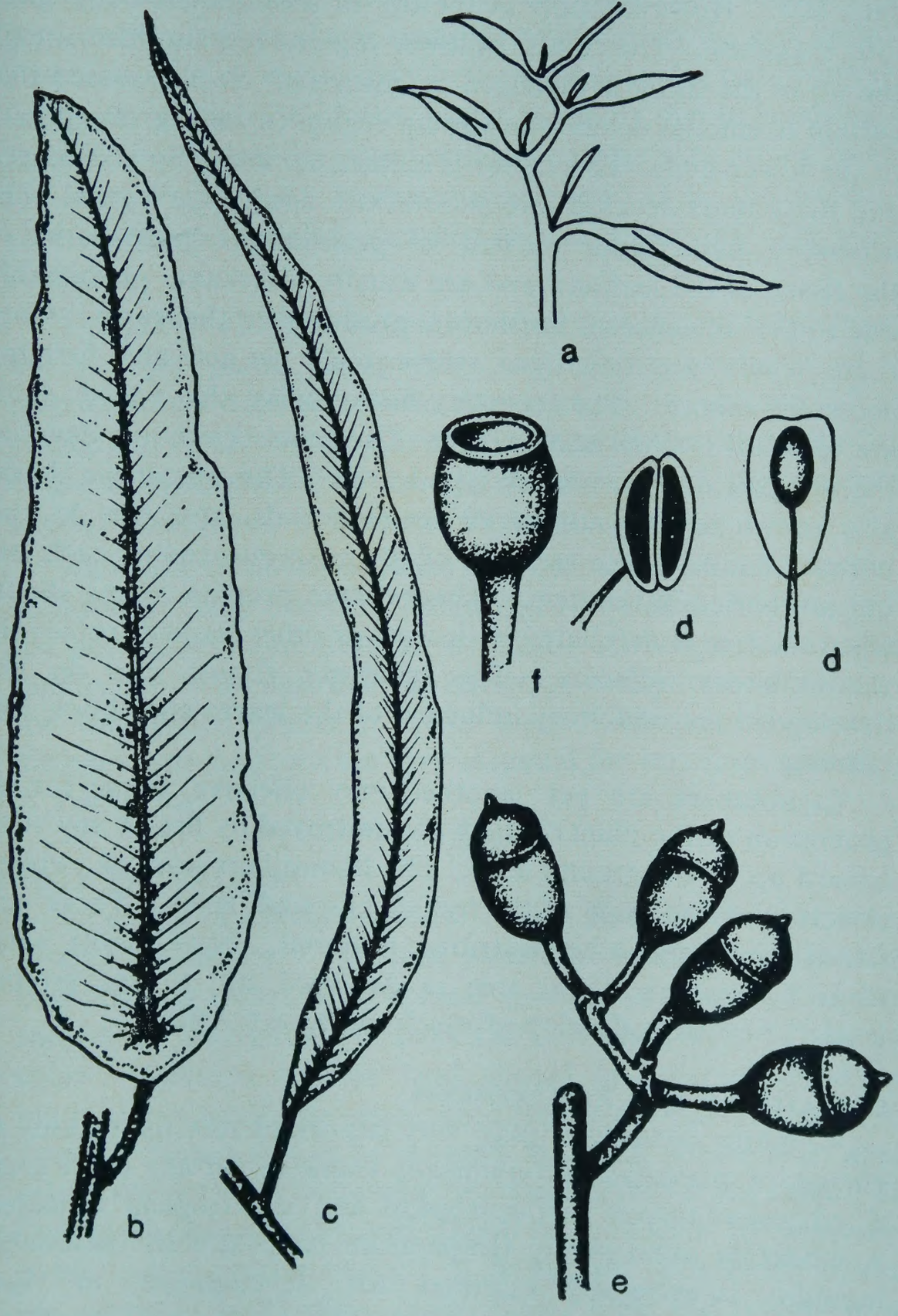

Fig. 1 — a, Juvenile leaves; b, Intermediate leaves; c, Adult leaves; d, Adnate anthers; e, f, Fruits with valves

E. citriodora is characterized by the presence of three kinds of buds, i. e. (i) naked, (ii) accessory, and (iii) epicormic. The naked buds unprotected by any covering, occur in the axil of each leaf. However, only at the tip of shoots these buds grow into branches. The buds at lower regions remain dormant till the tip of the shoot is damaged or destroyed. It is assumed that certain hormones develop in the tip region to inhibit the growth of the lower buds. This factor is eliminated if the tip is damaged and these buds develop into shoots with adult type leaves. The accessory buds occur as pads of meristematic tissue buried in the tissue of the leaf-axil and are usually dormant, presumably due to the influence of hormones produced in the leaves. Once these leaves are destroyed, these pads get activated forming accessory shoots. The accessory buds, unlike the naked buds are resistant to frost and drought. The accessory shoots develop the first pair of intermediate type leaves. The epicormic buds, also known as proventitious or dormant buds, give rise to epicormic shoots. These are pads of tissue accompanying each leaf but not buried in the stem. These tissues produce young shoots when the tree is defoliated by insects or other hazards removing the inhibitory influence. The epicormic shoots also do not develop till the inhibitory influence of the leaves and shoot tips remain.

Lignotubers are yet another very effective tissue for regeneration of the plants if they are destroyed by fire or any such hazard up to the ground level. The lignotubers arise as swollen structure at the base of the tree at ground level. These are full of starch and other nutritive material. New shoots arise from lignotubers if the tree is damaged up to the ground level. New trees develop afresh from these tissues.

Climate and Soil Requirements

Climatic conditions play very important role for making *E. citriodora* plantation economically viable as for any other crop. *E. citriodora* thrives well in tropical and sub-tropical climates. A moderate atmospheric temperature coupled with reasonable humidity is extremely essential for development of these plants in early stages of growth. Seeds do not germinate if atmospheric temperature is either very high or very low. Germination is best during the periods from mid February to

mid April and July to middle of November when temperature oscillates between 15° and 30°C approximately. Desiccating high temperature during May and June, and low temperature during December and January are the most unfavourable for germination. Even if the seeds germinate, they do not survive. The moist climate during July to September is also not favourable for seedlings because of very heavy mortality due to incidence of fungal diseases besides other physical damages to young plants by heavy rains. At temperatures below 15°C the growth of plants is proportionately retarded and at about 0°C the plants even die.

The plants of *E. citriodora* are very sensitive to frost injury, the younger plants being more so. Frost resistance of the tropical forms decreases with the increase in altitude of the plantation sites. It is, therefore, advisable that altitude of the origin of seeds should be close to the altitude of the proposed site for raising new plantations for better results.

An acidic to mildly alkaline soil with some organic matter is suitable for these plants. Waterlogged as well as bouldery soils are not suitable and must be avoided. Although a very rich humus soil is not desirable for nursery, the requirement of humus for established plants is quite high. Adequate amounts of nitrogen and moisture are very essential for luxuriant growth of *E. citriodora*.

Field Preparation

Selection of suitable land for raising *E. citriodora* plantation is very important. The land should be levelled and free from boulders and stones for a normal growth of roots. The land should be ploughed 2-3 times and pulverised well. Grass and other vegetation on the land should be collected, dried and burnt and it should be made weed-free to the maximum possible extent. Slopes should be terraced to make subsequent application of fertilizers and irrigation meaningful for the crop. The final preparation of the land should be preceded by applying a basal dose of superphosphate @ 60 kg./ha. For direct seeding the prepared land, ridges about 10 cm. high and 10 cm. broad should be made at 90 cm. apart and seeds sown on these ridges. In case of transplanting the seedlings, pits about 20 cm. in diam.

and 15 cm. deep at 90 × 75 cm. spacing should be made. If possible a handful of farmyard manure should be put in each pit before transplanting the seedlings.

Propagation

E. citriodora is raised only by seeds, and vegetative propagation is still not known. The seeds are very small and approximately 240 seeds weigh one gram. Only bold and healthy seeds should be used. Shrivelled seeds must be discarded. These germinate in 4-14 days depending upon atmospheric humidity and temperature. However, cold-stored seeds germinate even in 2-4 days. A commercial cultivation of the crop requires either raising a nursery or alternatively direct seeding the well prepared field in proper season.

Raising the Nursery

The nursery is raised on raised beds or even in trays filled with soil. A permeable sandy loam soil is the best for nursery while clayey and bouldery types must be avoided. The nursery must not be rich in humus since it promotes damping-off disease under humid conditions. It requires protection from direct sun and rain. Soil must be weeded, pulverised and levelled before seeding. Care must be taken while sowing that seeds do not go deeper than 1 cm. under soil, or else they may not germinate. Line sowing is advantageous for subsequent agricultural operations. After sowing, the seeds should be lightly covered with soil by gentle working with hand and irrigated so as to keep the soil fairly moist till the commencement of germination. Thereafter, the nursery should occasionally be irrigated to keep it just moist.

The next phase of propagation is transplanting of the nursery-raised seedlings in suitable containers for which polythene bags (15-20 cm. long and 10-12 cm. broad) are considered very good. Seedlings, with 2-4 pairs of leaves (about 2-3 cm. tall), and 4-6 weeks after seed sowing, are at the proper stage for transplanting. Older seedlings develop an extensive root-system which is very sensitive to even a mild disturbance resulting in very high mortality. Individual seedlings are pricked out on a spatula with a ball of earth attached, and 4-5 seedlings are transplanted in each bag filled with nursery-type of soil followed by

irrigation. These seedlings are allowed to grow for 2-6 months in the bags depending upon the season.

Nursery can as well be raised directly in bags. About ten seeds are sown in each bag, mixed with soil and irrigated. Plant population can be thinned out after germination and plants grown as such for 2-6 months as in the earlier case. This method is better and economical than the conventional method of raising nursery since the cost of raising nursery in beds and transplanting in bags is eliminated besides reducing the risk of mortality after transplanting in bags.

Transplanting

As mentioned above the seedlings grow in the bags for 2-6 months, which depending upon weather conditions attain an average height of 30 cm. At this stage polythene cover may be slitted or even completely removed and seedlings with ball of earth intact are transplanted, without disturbing the roots, in pits at predetermined spaces. The space around the seedlings must be compactly filled with earth and irrigated the same day. Delay in irrigation causes retardation in growth thereby reducing yield of distillable herb.

It has been inferred on the basis of repeated experiments that a spacing of 90 cm. between rows and 75 cm. between pits is the best for raising a commercial crop of *E. citriodora.* Initially each pit will have 4-5 plants and the population can be thinned subsequently. It has further been observed that transplanting in field is preferable in August or early September in frost-free regions. This timing will allow sufficient time for the young plants to establish and to withstand the adversities of winter. Regions experiencing frost during winters would not be suited for August-September transplanting. February is the best for transplanting in such areas. The plants will grow quite fast during subsequent months and will be able to survive during summers with even light irrigation. By advent of rainy season these plants would have grown to a height and strength enough to withstand any physical damage due to heavy rain and even fungal attack. Mortalities, if any, can successfully be replaced towards the end of the rainy season.

Once the plantation has survived the rainy season, it is fully established with least chances of any serious damage during

winters. However, to check weed control the plantation requires hoeing during the first year. The roots of *E. citriodora* grow quite deep after a year and weeds do not pose any threat to the plantation. Moreover, regular subsequent agricultural operations keep the weeds under control.

Field Sowing

The raising of nursery and transplanting the seedlings can be eliminated completely by sowing seeds directly in the field. However, this method requires a very good preparation of land, thorough removal of grass, followed by sowing in rows at 90 cm. and irrigation. It is better to prepare small ridges, about 10 cm. high and 10 cm. wide, 90 cm. apart and seeds sown on the ridges. This method prevents seeds from drifting away on irrigation. Sudden rains or heavy irrigation also does not affect the crop sown on ridges. Seeds can be sown in February and September. The plantation can be thinned according to requirements. This method is cheaper than raising nursery and transplanting seedlings. However, it cannot be adopted in regions exposed to heavy rainfall and frost.

FERTILIZER AND ITS APPLICATION

The available data on fertilizer requirements of eucalypts in general and *E. citriodora* in particular is very scanty. Nitrogenous fertilizers contribute positively towards increased production of leaves which indirectly increases oil production per unit area. The fertilizer has no bearing with the percentage of oil in leaves. Phosphate and potash fertilizers do not appear to have any effect on the crop and hence are not recommended for regular use unless the soils are very deficient in these ingredients. However, in due course of time the soil becomes depleted in the essential ingredients which subsequently causes deficiency diseases. Hence, a small dose of phosphatic and potash fertilizers should be given to the plantation every year. It is, accordingly, suggested that in irrigated areas about 20 kg. N, 30 kg. P and 30 kg. K per ha. should be applied at the time of ploughing as basal dose. Three top dressings of N in the form of urea or ammonium sulphate should be given @ 20 kg. per ha. preferably after every harvest. Fertilizer application should necessarily be followed by irrigation. In rainfed areas

Fig. 2—*E. citriodora*

fertilizer should be applied during rains. The above dose of fertilizers should be repeated every year.

Harvesting and Distillation of Herb

Care must be taken to harvest the crop when leaves are the richest in oil-content and weather is also quite clear. Cloudy as well as rainy days are unsuitable for harvesting. The first harvest can be taken from 6—8-month-old plantations. At this stage the yield of the herb as well as of the oil is rather negligible, but coppicing the plants is very necessary since it promotes a vigorous sprouting of side branchings. Fresh shoots sprout in about four weeks after coppicing which are again ready for coppicing after 4-5 months. This process results in regular increase in yield of herb which is almost stabilized after plants are 3-year old. The first coppicing is done at about 30-45 cm. above ground and the subsequent ones are done at 75-90 cm. above ground (Fig. 2). This level of coppicing is advantageous for subsequent cultural operations. Usually three

Fig. 3—Twig of *E. citriodora*

harvests can be taken annually from the irrigated plantations corresponding with the maximum oil content of leaves. This stage is reached during middle of February to middle of March, middle of July and end of October to early November. This provides the fresh shoots to grow for nearly four months during which period the leaves also reach adulthood (Fig. 3)—the best stage for oil content. After two years, the plantation can be thinned to one plant per pit so that new shoots get enough space and nourishment to grow normally.

The Australian method of coppicing plants at about 15 cm. above ground makes each plant a huge bush even from the ground level. This requires more spacing between plants and the number of plants per acre is accordingly reduced. Much damage to shoots is unavoidable while hoeing in such plantations and the yield of herb per unit area is less as against the area pollarded at 75-90 cm. above ground. It has repeatedly been observed that at the above spacing and coppicing the yield of green herb per ha. during the first year is approximately 7 tonnes, during the second year about 30 tonnes and about 40 tonnes during the third year in irrigated areas. This yield is almost stabilized after this age and a plantation is expected to remain economical for about ten years if properly maintained. From unirrigated rainfed areas only two harvests with nearly 37 tonnes of green herb per ha. per year is possible. A pronounced shoot potentiality of *E. citriodora* ensures a regular supply of green herb after each coppicing. The harvested material should immediately be separated from hard, thick wood since leaves attached to only about pencil thick or thinner branches are suitable for distillation. The herb should immediately be distilled. On storing, the leaves either dry or even decay if not regularly up-turned resulting in a substantial loss of oil. Separating leaves completely from thin branches is not advisable from economic point of view. The mixture of leaves and thin branches is roughly in the proportion 7:3. Such a herb from an hectare of irrigated plantation on an average yields 200 litres of oil while from an unirrigated land about 150 litres of oil. This, according to the present market rates @ Rs 40 per litre costs Rs 8,000 and Rs 6,000 respectively. Besides oil, a hectare of plantation also yields about 11 tonnes of dry wood suitable for paper pulp industry and fuel.

Distillation of the Leaves

The leaves are steam distilled for the oil. It is advisable to distil the herb soon after harvesting to avoid loss of oil through evaporation as well as its deterioration in quality during storage. Leaves attached to about pencil thick twigs should manually be separated from thicker branches and charged in stills. Stills are designed to allow steam to enter at the base and to go out into the condenser through the top. This allows steam to

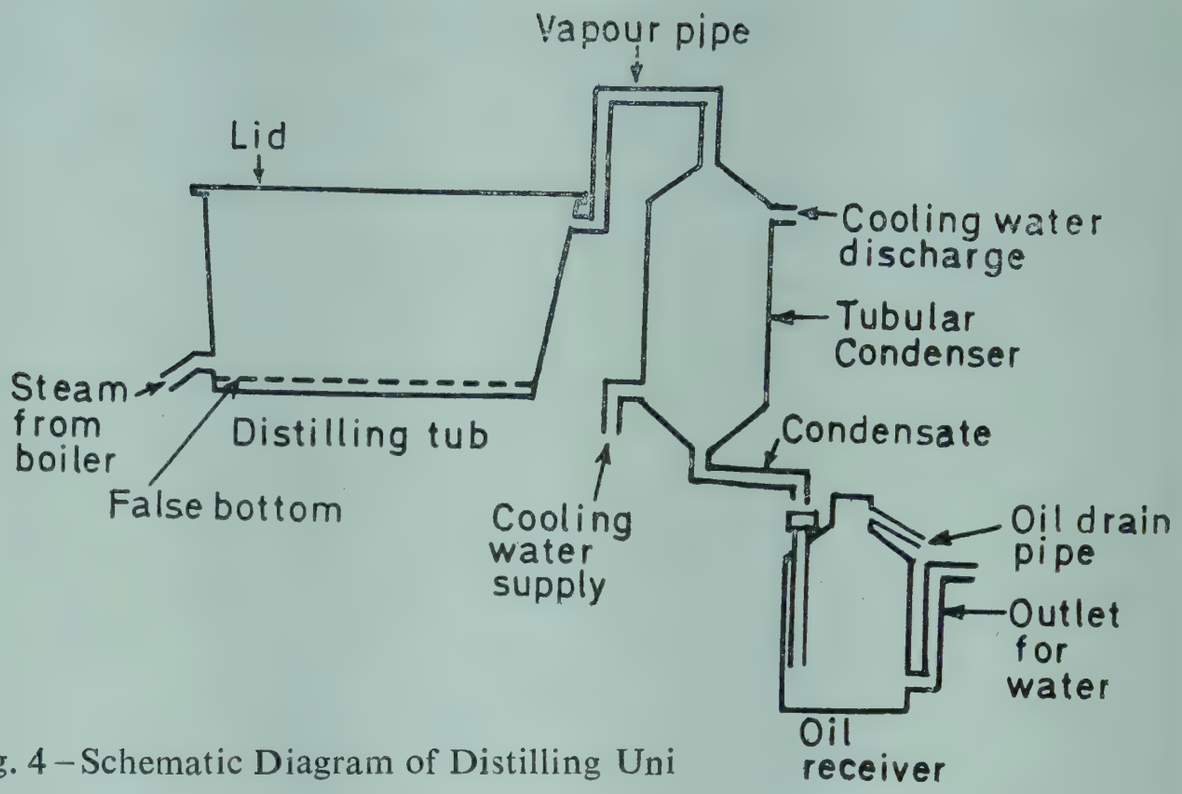

Fig. 4 – Schematic Diagram of Distilling Uni

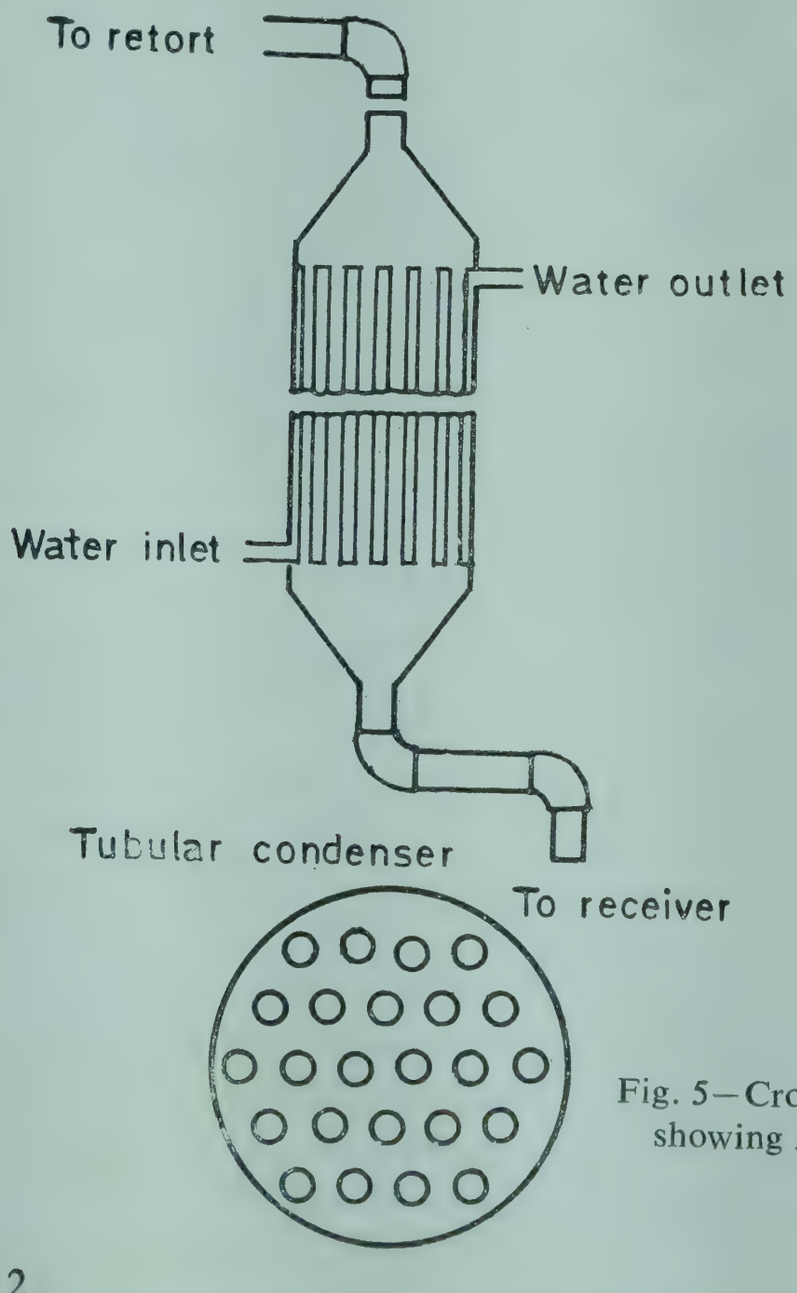

Fig. 5 – Cross-section of Condenser showing Arrangement of Pipes

Fig. 6 — Hairy Caterpillars on *E. citriodora* Leaves

circulate through the entire still ensuring maximum yield of oil from the charge. After distillation stills are cooled, emptied, cleaned and recharged with distillable material. It is better to keep a battery of alternate stills running while the remaining ones are being prepared for running. After condensation the oil floats over water in trays fixed at the outer end of condensers and the same is separated from water easily. The distillation unit can be operated with coal-fed or oil-fed boiler. Small units can be operated with fuel wood as well.

Pests, Diseases and Their Control

Although a list of many pests and diseases of eucalypts growing in Australia is available, the problem is not serious in India. Some of the common pests and diseases may be mentioned. Certain areas are known for termite menace. If the soil is dry for a considerable time termites eat away the roots and bark of

Fig. 7—*E. citriodora* Leaves attacked by *Colletotrichum* sp.

the stem causing plant mortality. It is, therefore, essential to treat the soil with Endrin mixed with water or 0.1-0.2% aqueous solution of Tafdrin or Chlordin besides not allowing the soil to remain dry for more than a fortnight. The hairy caterpillar also feeds on leaves of *E. citriodora* (Fig. 6) in early stages and can be controlled by timely spray of BHC powder on leaves. Certain fungal diseases seriously affect these plants. *Fusarium orthoceros* attacks the seedlings at the hypocotyl level in the rainy season. Excessive humus content of the soil promotes the disease and entire nursery perishes overnight. The fungus *Colletotrichum* sp. attacks leaves (Fig. 7). The leaves turn brown and die with the spread of the fungus. Aqueous spray of Micop (0.2%) or any other copper fungicide controls the disease. In addition to the above, some viral infections causing phyllody (little leaf), leaves turning pink or yellow and some other mosaic symptoms have been observed. Plants showing these symptoms should immediately be plucked and destroyed.

ECONOMICS OF CULTIVATION

It has earlier been indicated that a hectare of 3-year-old *E. citriodora* plantation is expected to yield 250 litres of oil under irrigated conditions and 200 litres of oil annually from un-irrigated areas. This, according to prevailing market rates (Rs 40/litre) will cost Rs 10,000 and Rs 8,000 respectively. During the 2nd year the oil yield per ha. would approximately be 150 litres and during 1st year only 50 litres valued at Rs 6,000 and Rs 2,000 respectively. However, the expenditure incurred on such plantations also has to be accounted for in a commercial enterprise. Nursery and plantations during the first year involve high investment while return is negligible. But

this must not be a cause for alarm. The plantation shows encouraging signs even from the 2nd year. The expenditure on nursery and on the 1st year of plantation per hectare is as follows.

Expenditure on Nursery for One Hectare Plantation

	Rs
1. Filling 9000 bags with soil and transporting the same to suitable site	200
2. Sowing seeds and irrigation	30
3. Maintenance of nursery	1000
4. Miscellaneous	70
Total	1300

Expenditure on Plantation During 1st Year

1. Ploughing and levelling the land	150
2. Collection of grass, etc.	150
3. Making 8750 pits	250
4. Transporting and transplanting seedlings	350
5. Hoeing (twice)	300
6. Cost of fertilizer	200
7. Irrigation (thrice)	200
8. Harvesting	50
9. Distillation	1000
10. Miscellaneous (rent of land and interest on Capital)	250
Total	2900

The oil produced during the 1st year would hardly cost Rs 2,000. From the 2nd year onwards the expenditure up to transplanting stage is eliminated while production of the oil goes up. The annual expenditure practically stabilises during the 3rd year and the plantation shows definite profit. The expenditures incurred during 2nd and 3rd year on one hectare basis are :

Cost of cultivation during 2nd and 3rd year (per ha.)

Item of expenditure	2nd yr. (Rs)	3rd yr. (Rs)
1. Three hoeings	500	500
2. Cost of fertilizer	500	500
3. Irrigation (5-6 times)	500	500
4. Harvesting	1000	2000
5. Distillation	2000	2500
6. Miscellaneous (rent of land and interest on Capital, etc.)	500	500
Total	5000	6500
Estimated cost of oil	8000	10000
Expected profit	3000	3500

The above returns are expected from irrigated areas. If the plantation is dependent on natural rains for irrigation, a hectare of plantation will produce approximately 150 litres of oil during the 2nd year and 200 litres during the 3rd year. Such plantations are also expected to show per hectare, an annual profit of Rs 1,000 during 2nd and of Rs 2,000 during the 3rd year (accounting for expenditure of only Rs 1,500 for two harvests) besides about 11 tonnes of wood suited for paper pulp and fuel. Thus, it is evident that the enterprise will be economical and profitable.

Constituents of the Oil and its Uses

The oil of *E. citriodora* is a high grade perfumery oil much demanded in the perfumery industry. The cost and acceptability of the oil depends upon its citronellol and citronellal content, the main constituents of the oil. Higher the content, the oil has better market value and acceptability. The oil is colourless with a very pleasant smell, sp. gr. at 15°C varies between 0.8658 and 0.8740 and refractive index at 20°C varies between 1.451 and 1.456. Its chemical composition is not very simple. It contains citronellal, citronellol, geraniol, esters, pinene, cineole and isopulegol. In fact isopulegol is formed by enolisation of citronellal during storage. Citronellal is the major fraction of the oil varying between 65% and 80% followed by citronellol, 15-20%. Esters and other fractions are only in traces.

The oil is used in perfumery and as a source of citronellal for manufacture of citronellol, hydroxy citronellal and menthol. A small quantity of oil is added in germicides and disinfectants to improve their odour. It is an effective substitute for Java Citronella oil and also used in soap and cosmetics industry. The wood of *E. citriodora* is used as mine props, railway sleepers and in construction of houses. The wood has an excellent pulping property and can be used in paper industry.